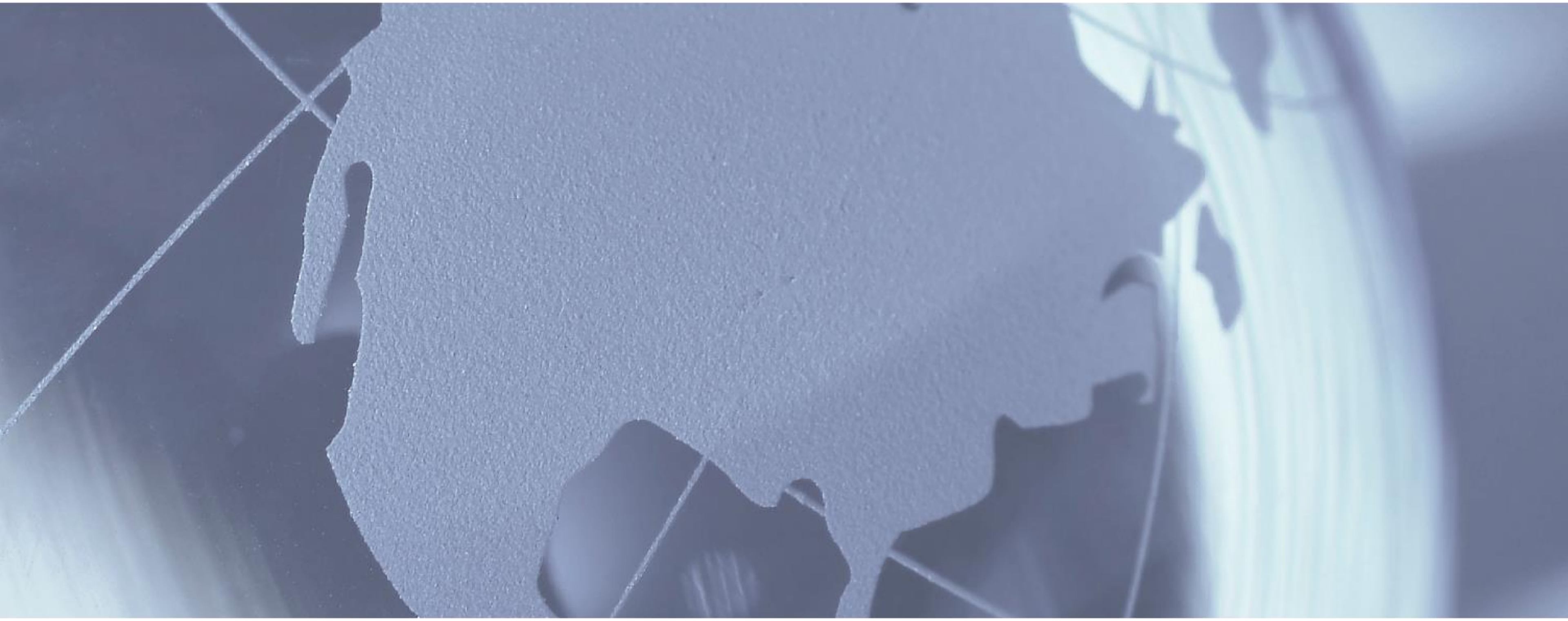

NOAA Perspectives on CubeSats

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Committee on Achieving Science Goals with CubeSats

Space Studies Board | National Research Council

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NOAA Interest in CubeSats

- **Question #1: What is your agency doing right now in the CubeSats field?**
  - NOAA is assessing the CubeSat activities conducted by others: NASA/ESTO, DoD, Academia, Commercial, International
- **Question #2: What are current investments or strategies?**
  - NOAA is planning to study the ability of CubeSats to meet some of NOAA's requirements for satellite observations.
    - FY 2015
      - (1) Study with MIT / LL on ability of CubeSats to provide microwave soundings
      - (2) With JPL and Aerospace Corporation on ability of CubeSats to provide infrared soundings
    - FY 2016: $10M in President's FY 2016 request to initiate work on a microwave sounder on a CubeSat as partial gap mitigation for JPSS / ATMS
    - Future Architecture development activities beginning in FY 2015–16 will assess CubeSat applications to NOAA mission

NOAA Interest in CubeSats

- **Question #3: Why is your agency interested in CubeSats?** (Examples: Educational purposes, responsiveness to data needs, tech demos)
  - To determine if they can be used to help us meet NOAA requirements for global Earth observations in a more affordable manner

- **Question #4: How successful are the current projects? How is that success measured?** (Examples: technological demonstrations? Science results? Data volume?)
  - Currently reviewing the progress of other organizations

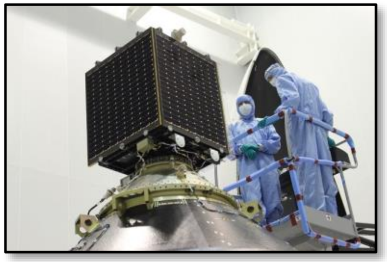
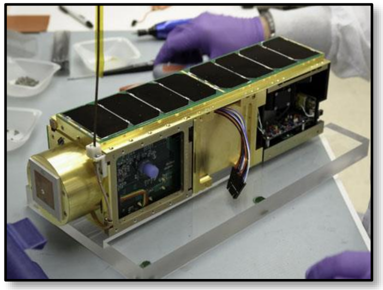
Set of NanoRacks CubeSats is photographed by an Expedition 38 crew member after the deployment by the Small Satellite Orbital Deployer (SSOD). Feb. 11, 2014. Credit: NASA

NOAA Interest in CubeSats

- **Question #5: What are the obstacles the agency is facing with respect to CubeSats?** (Examples: launch availability, policy obstructions, ground stations, orbital debris, etc.)
  – Launch availability, orbital debris, and radio frequency spectrum allocation may be the biggest obstacles. All of these obstacles will need to be explored in the future. NOAA will also leverage the results of other agencies, such as NASA and DoD, in their efforts to overcome the same obstacles.

- **Question #6: What do you think will happen in the next 1–5 years?**
  – If the obstacles mentioned above can be overcome, then we will determine what future risk reduction investments and demos we want to make—always with the goal in mind to help us improve our ability to monitor and predict weather and climate.

Satellite Classes

Examples	 LANDSAT-8	 TACSAT-2	 PROBA-V	 O/OREOS
	Large	**Small (Mini)**	**Micro**	**Nano**
	> 500 kg	**<500 kg**	**<100 kg**	**<10 kg**

CubeSat

- 1U: 10 cm x 10 cm x 10cm
- 1U: ~1.3 kg
- Cubesats can be multiple ‘U’
- ~230 launched to date
- Standardized interfaces, launchers and components

Why the Government is looking at SmallSats and CubeSats

- Potentially adds more capability to the current constellations
- More frequent revisit opportunities with constellations
- Flocks can be launched to perform multiple functions (e.g., comms, EO/IR, TTL, etc.)
- Gap mitigation
- Refresh technology every 2–3 years
- Scalability—.5U, 1U, 1.5U, 2U, 3U, 6U, 12U
- Opens up new ventures with the commercial sector for Space Services (WorldView, SkyBox, Planet Labs, etc.)

Cost, Speed, and Launch

- **Cost and Speed drivers**
  - CubeSats are low-cost satellites, and are an emerging R&D area with civil and military applications. Ultra-small CubeSats can be fabricated quickly (developmental design) as secondary payloads. Many universities and research labs are building and launching small satellites.
  - CubeSats have rapid refresh capabilities. Life span is 2-3 years in LEO. While on orbit, the next generation can be developed and readied for launch

- **Multiple launch vehicle capabilities are available or coming on line to launch CubeSats**
  - CubeSats can be launched in ‘flocks” and can have different complimentary sensor and comms packages

Evolving Capabilities

- Cognitive software defined radios, tunable on orbit; CubeSat Lithium on-the-fly selectable frequency radios
- Software reprogrammable on orbit
- Automatically adjusts for Doppler
- NSA Suite-B encryption compliant
- 3-Axis ADCS (sun sensors, magnetometer, momentum wheel, gyro, Star tracker, etc.)
- On-board cameras (Electro-Optical; 3 band spectral, etc.)
- Dual band (UHF and S-Band data down link); IRIS X-band transponder and S-band crosslink for deep space; free space laser communications is next
- Store and forward data downloads to ground station
- Propulsion and power systems: solar, chemical, cold gas, electrical propulsion, etc.
- Bus standardization

CubeSat Launch Capable Vehicles

Launch Platforms	Status	Sponsor
International Space Station (ISS) CubeSat Deployers	Operational since 2014	NanoRacks
ALASA F-15 pod	FY16 (testing FY15)	DARPA
Altas V (rideshare)	Operational	NRO
Delta IV (rideshare)	Operational	NRO
Falcon 9 v1.1	Operational (supply to ISS)	SpaceX
LYNX (piloted 2-seat shuttle)	FY16 (testing FY15)	XCOR Aerospace
LauncherOne	FY16	Virgin Galactic
DARPA XS1	FY18	DARPA
Super Stripi aka SPARK	FY15/16	Sandia/U.of HI/Aerojet
Minotaur-4	Operational	AF Space Command
Exploitation Mission 1 (EM-1) (lunar dispenser)	FY18 (1st biology experiment beyond LEO since Apollo)	NASA Ames
EM-2	FY21 (lunar orbit)	NASA Ames
Space Launch System (SLS)	FY18	NASA
JAMASS	FY15/16 (launch US cubes)	Japan Manned Space Sys

What's Next?

- Commercialization of Space—"Cosmic Shift" ("commercial space revolution") IQT (2015) The New Race for Space, Vol 6 (3), IQT Quarterly.
  - New business models
  - Decreased cost to access space
  - Adoption of commodity hardware, circuits, rapid prototyping and the effects of Moore's law – doubling of computer power. Result, a single satellite design can evolve through 10 generations in one or two years—taking advantage of HW that did not exist at the inception of the design cycle
  - Common analytic engines and services—emergence of proprietary and open source analytics engines have enabled companies to sell affordable analytic products, not just raw data
- CubeSats are no longer just in LEO orbit. CubeSats are being developed for inter-planetary exploration.
- Government agencies are looking at CubeSats as a gap filler (NRO, NGA, etc). Government must consider implications to how they currently plan, buy, and use commercial space services and products
- New sensing modalities (HSI, SAR, etc.)
- Bus standardization
- Ever-increasing demand for launch services

Summary

- NOAA is interested in CubeSats as potential Gap Mitigation and for playing a role in future space architectures
- NOAA looking to leverage the investments of NASA and other partners to begin developing CubeSat capabilities, starting with EON-MW in FY 2016
- NOAA envisions that CubeSats may play a role as an element in NOAA's observation system